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PROFITABLE MANAGEMENT OF SHORTLEAF AND LOBLOLLY PINE FOR SUSTAINED YIELD

by

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The Occasional Papers of the Southern Forest Experiment Station present information on current southern forestry problems under investigation at the Station. In some cases these contributions were first presented as addresses to a limited group of people, and as "occasional papers" they can reach a much wider audience. In other cases, they are summaries of investigations prepared especially to give a report of the progress made in a particular field of research. In any case, the statements herein contained should be considered subject to correction or modification as further data are obtained.

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INTRODUCTION AND GENERAL RECOMMENDATIONS

Maintenance and stabilization of land ownership and of the timber industry with its associated communities in the shortleaf and loblolly pine region depends very largely on keeping forest lands continuously productive. A system of sustained-yield management, which in a practical way correlates the economic requirements of forest owners of this region with those measures necessary to maintain and build up the forest resources, is described in this paper. The conclusions and general recommendations can be stated briefly as follows:

Fire Protection

Protection from fire in the shortleaf-loblolly pine-hardwood type of forest is, in general, not adequate unless it limits the area burned each year to less than 1 percent of the total forest area protected.

Regulation of the Cut

To safeguard future yields of timber the maximum volume cut from a forest property during any period should not exceed the estimated growth of merchantable timber during the period. In forests not up to capacity production, in order to increase future yields the annual cut usually should not remove more than 80 percent of the annual growth. The total volume of timber on a large property and its rate of increment can be determined most economically by a preliminary survey, in which the entire forest is covered systematically, although the sample plots on which the trees are measured need not total more than 1 percent of the entire area. Such a non-intensive cruise does not attempt to map or determine volumes of bodies of timber, but it provides the basis for a determination of the cut. A generalized, flexible, and inexpensive plan of management will suffice for the whole forest until local, first-hand experience in growing timber on specific subdivisions of the property can furnish a basis for more detailed specifications of management. Early subdivision of the property into permanent compartments for management, administration, and utilization purposes is desirable.

Cutting Procedures

The relatively high and constantly increasing accessibility of southern pine forests permits the rapid extension of logging operations over large areas. Cuts should be made at 5- to 10-year intervals in all commercial stands, and not more than 25 to 35 percent of the merchantable growing stock should be removed in any one cut. The less promising trees should be removed from all merchantable size-classes, the selection being made on the basis of their relative financial maturity. No trees should

be cut until marked by a reliably trained crew working under the supervision of a competent forester. Proper selection of reserved trees will build up growing stocks and provide for a very desirable shift in the major portion of the future growth and yield from the smaller and inferior trees to the larger and better ones. The marking crew should tally all merchantable sawtimber to be cut and all to be reserved. Such a record serves not only to control the proportion of the current cut, but also will be valuable later in checking net rates of volume growth, by comparison with subsequent records of the same sort.

Profits

The crucial question in the commercial application of any constructive program is: "Will it pay?" In second-growth forests the greatest possibility of profit lies in a combination of selective cutting with a skillful integration of utilization for various forest products. Only in this way can advantage be taken of the wide variation in values between trees suitable for specific purposes. The method of management recommended here is based on these principles, and it is believed that such management will prove more profitable in this type than clear-cutting or other methods now in use.

Stands of about 3,000 board feet per acre, on average sites, generally may be expected to yield an annual profit of $1.00 per acre under existing market conditions, and the prospects are bright that this profit can be increased by good management.

DEFINITION AND NATURE OF SUSTAINED-YIELD MANAGEMENT

Sustained-yield forest management probably has never been better defined, from the practical standpoint, than in Schedule C of the Lumber and Timber Products Code:[1/]

"Sustained-yield management is defined as management of specific forest lands under single ownership or cooperative control within an economic unit, under a definite management plan which limits timber cutting to the capacity of such forest lands under existing methods of management, as determined from existing growing stock and growth, to provide without interruption or substantial reduction raw material for industry and community support."

This definition, approved after careful consideration by a committee representing public and private forest agencies established in connection with the Lumber and Timber Products Industry Code of 1933, clearly excludes from designation as products of sustained-yield management the low minimum-rate yields from neglected and mismanaged forests, even though these yields may have become stabilized. This exclusion is reasonable because, as will appear later in this paper, such mismanaged and neglected forests cannot produce more than a fraction of their potential yields in volume and quality. The mismanagement in such forests is usually characterized by premature cutting of developing trees and stands; removal of better trees and species, leaving the poorer ones to occupy the ground; failure to cut so as

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1/ Lumber Code Authority Bull. 95. Section 2 (9) of Schedule C, page 4.

to regulate the stand density; neglect of regeneration; and disregard of protection against fire and other sources of damage. Therefore, low yields may be continuously forthcoming without attaining true sustained-yield management.

Although the code definition rightly emphasizes the continuity of yield "for industry and community support," it also infers, though it does not specifically so state, that the yield of forest raw materials of higher quality should be sustained, i.e., not mere volume production is to be sought but quality production as well. For profitable management this is of the first importance, which means that promising trees should be held until they approach real maturity, trees of inferior form should be removed early, stand density should be regulated, and the more desirable species should be favored.

It follows that in starting sustained-yield management of forests not previously managed systematically, yields based on maintenance of the present unsatisfactory conditions are not enough. As rightly emphasized in the code definition, however, initial yields must be calculated on the basis of "existing methods of management, as determined from existing growing stock and growth." In other words, the cut at the beginning should not be so great as to cause further deterioration of the forest. Sound plans of management, however, almost universally make further provisions and provide for building up the forest property to levels where it will provide a sustained yield of <u>greater volume</u> and <u>higher quality</u>.

Aside from protection against fire and other adverse influences, one of the first tasks of forest owners or groups of owners wishing to initiate a sound sustained-yield policy, looking to a progressive betterment of their forestry property, is to fix upon a safe annual cut under existing conditions. Increase of the cut will be warranted as conditions are improved. This forces the forest owner or his authorized representatives to confront the chief problems of sustained-yield management: determination of the present volume and quality of the growing stock, the possibilities of improving it, and measures to insure this improvement.

While sustained-yield management can be applied with various degrees of profit to the majority of forest properties in the shortleaf and loblolly pine region, it must be recognized that there are many properties that do not qualify for this type of management. For example, there are large areas on which the timber has been liquidated, or on which liquidation will be completed within a few years. On these properties the growing stock has been so depleted that, under continuous management, returns will not meet carrying charges for many years. Unfortunately, reclamation of these depleted forest areas must remain for a long time one of the important problems of this region, imposing a burden on other productive land. Sustained-yield management, as described herein, does not contemplate measures which may require a lifetime, such as the restoration of seriously depleted forests or the production of a new growing stock by seeding or planting on bare land. On the contrary, a system of management is recommended which can be applied profitably to such thrifty second-growth stands as now commonly exist in many parts of this forest region. If good forest management is attained for these stands, the forest resources and forest industries in this region will be maintained or even increased, so that a continuous flow of income to labor will result and community interests will continue to be safeguarded.

THE FOREST GROWING STOCK

Sustained-yield forest management aims to obtain the maximum net returns over a long period. The size of the income from a forest property depends primarily upon the amount and value of present yields from existing stands and upon the extent that these yields are increased in volume and value under management. Since the condition of the growing stock and the possibilities of improving it are such important factors in sustained-yield management, they are discussed here in some detail.

Definition

For practical purposes the growing stock may be defined, as a whole or in part, as follows:-

The total growing stock on a given area consists of all trees growing thereon of whatever age and species. It includes seedlings, saplings, and trees of pole- and sawlog-size, whether merchantable or unmerchantable. It is best evaluated by stating the number of trees in each diameter-class as shown by figure 1-A and the subjoined tabulation. It may also be measured in terms of basal area,[2/] as shown in figure 1-B. Partial measurement of stem volume can be expressed in cubic measure, as in figure 1-C and the subjoined tabulation.

Of more influence on immediate sustained yield than the total growing stock is that part which may be termed the merchantable growing stock, which consists only of trees in those size-classes which when cut and properly prepared will make some salable raw material. In southern pines very few such products can be made from trees below the 6-inch diameter-class (i.e., trees under 5.0 inches d.b.h.) so that this is ordinarily the smallest diameter-class for which basal area or volume need be computed.

Of still more significance is the sawlog growing stock, which is that portion of the salable species of a size and quality to make merchantable sawlogs. Although sawlogs are frequently made in the South from smaller trees, extensive studies have shown that profitable sawlogs can seldom be made from trees under 13 inches d.b.h. Sawlog growing stock may be measured also in board-foot volume, as shown in figure 1-D.

Timber Classes

In order to consider both the possible merchantable uses of the present growing stock as well as its possible future development under various cutting practices, an extremely useful procedure is to classify the growing stock into timber classes or groups of diameter-classes, as shown in figure 1, in which the following groups are designated:

2/ The basal area of a stand is the area in square feet of the total cross-sections of all trees in the stand measured at breast height ($4\frac{1}{2}$ feet above the ground).

Timber Class	Diameter at Breast Height	2-Inch Diameter-Classes
Seedlings	Under 1.0 inch	
Saplings	1.0 to 4.9 inches, incl.	2, 4 inch
Poles	5.0 to 12.9 inches, incl.	6, 8, 10, 12 inch
Small sawtimber	13.0 to 20.9 inches, incl.	14, 16, 18, 20 inch
Large sawtimber	21.0 inches and over	22 inch and over

A small portion of the pole stand (5 to 12.9 inches) is sufficiently straight and clear to be valuable for posts and poles, but the major portion of these tree sizes can yield only the low stumpage prices characteristic of pulpwood, fuel, and other cordwood.

In the small-sawtimber class those trees (usually not over 20 percent of the stand) qualified for high-class poles and piling have a high stumpage value, but they are still only moderately valuable for sawtimber, especially if in the smaller diameter-classes. One of the most recent logging- and milling-cost studies in loblolly and shortleaf pines reveals that 13-inch trees provide a margin (for stumpage, profit, and compensation for risks) of only $2.42 per M board feet.

In the larger-sawtimber class, 22-inch trees yield a margin of $9.91 per M board feet and 26-inch trees $12.56, for stumpage, profit, and risks. No data were obtained on larger timber. Obviously, operations in the larger size-classes not only yield much greater stumpage returns (earnings on the investment in land and growing stock) but provide safer margins to cover operating risks and profit. Not only are larger size-classes of the first importance in their effect on immediate revenues, but as will be developed later, they provide the foundation for current growth of high-value material.

Both the distribution of growing stock on the average acre and its distribution over the entire forest property have much bearing on management procedures, although the latter is less important on those properties all parts of which are accessible to logging operations. The quantity of the growing stock and its distribution in diameter-classes are determined by an inventory, as discussed under "Organizing a forest property under sustained-yield management."

Improvement of Growing Stock

In practicing sustained-yield management on a forest property attention should be given not only to current yields, but also to the improvement of the growing stock from which future production of high-quality timber must be obtained. A flexible program of cutting, which responds to changing markets and prices, rather than a rigid plan is desirable. In stands of second-growth shortleaf and loblolly pine of irregular density, composition, age, and quality, non-earning and low-earning timber should be liquidated in the order of its relative financial maturity, and higher-earning timber should be held until it approaches financial maturity. 3/ By this method of selection the productive capacity of the soil is directed toward its

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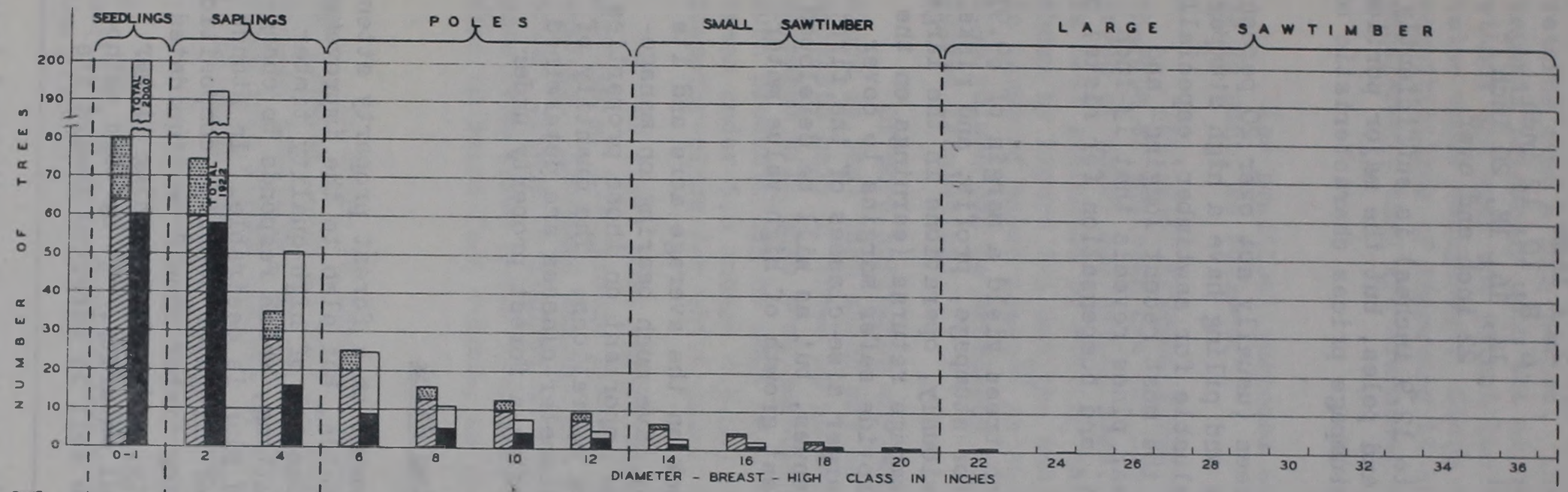
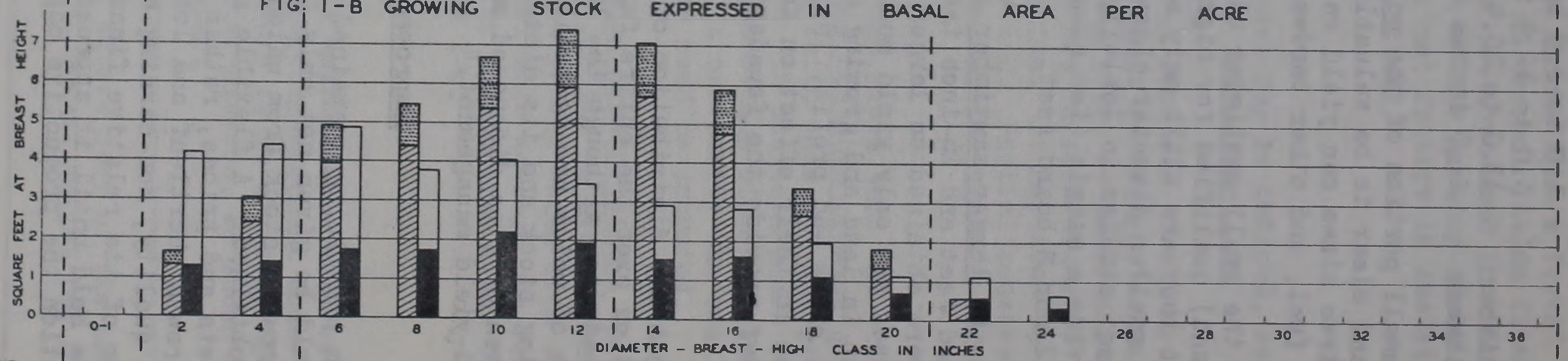
3/ Financial maturity may be defined as the time when the individual tree or stand will no longer make a profitable increase in volume or quality.

FIG I-A GROWING STOCK EXPRESSED IN NUMBERS OF TREES PER ACRE



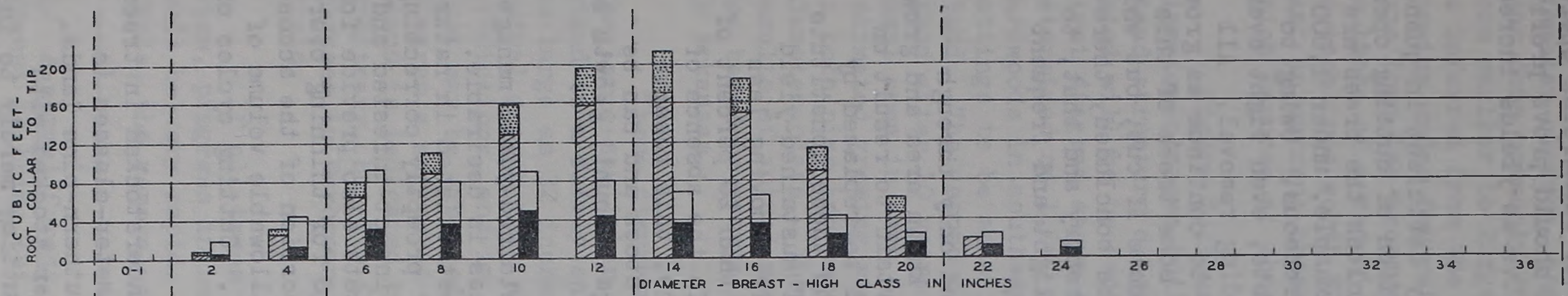
	NUMBER OF TREES PER ACRE												TOTALS
PINE													
DESIRABLE	64.0	59.8	28.1	20.1	12.6	9.8	7.5	5.3	3.4	1.5	0.6	0.2	53.0
UNDESIRABLE	16.0	14.9	7.0	5.0	3.1	2.4	1.9	1.3	0.8	0.4	0.2		212.9
TOTAL	80.0	74.7	35.1	25.1	15.7	12.2	9.4	6.6	4.2	1.9	0.8	0.2	265.9
HARDWOODS													
DESIRABLE	60.0	58.0	16.0	8.7	4.9	4.0	2.4	1.4	1.1	0.6	0.3	0.2	157.7
UNDESIRABLE	140.0	134.2	34.5	16.0	6.0	3.4	2.0	1.3	0.9	0.5	0.2	0.2	339.3
TOTAL	200.0	192.2	50.5	24.7	10.9	7.4	4.4	2.7	2.0	1.1	0.5	0.4	497.0
PINE & HARDWOODS	280.0	266.9	85.6	49.8	26.6	19.6	13.8	9.3	6.2	3.0	1.3	0.6	762.9
	280.0	352.5		109.8				19.8				0.8	

FIG. I-B GROWING STOCK EXPRESSED IN BASAL AREA PER ACRE



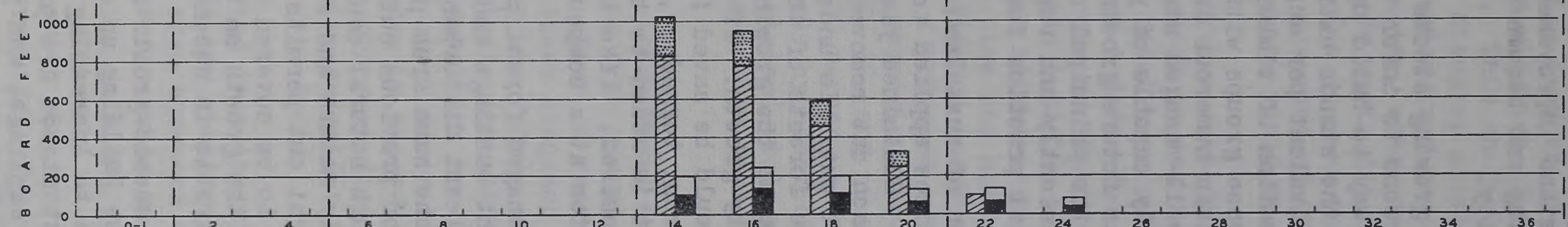
	BASAL AREA IN SQUARE FEET PER ACRE												TOTALS
PINE													
DESIRABLE	1.31	2.44	3.94	4.40	5.34	5.89	5.66	4.74	2.65	1.31	.53		36.21
UNDESIRABLE	.33	.61	.98	1.08	1.31	1.49	1.39	1.12	.71	.44			9.46
TOTAL	1.64	3.05	4.92	5.48	6.65	7.38	7.05	5.86	3.36	1.75	.53		47.67
HARDWOODS													
DESIRABLE	1.28	1.39	1.70	1.71	2.18	1.88	1.50	1.54	1.06	.65	.53	.31	19.41
UNDESIRABLE	2.95	3.00	3.14	2.09	1.85	1.57	1.39	1.25	.88	.44	.53	.32	15.73
TOTAL	4.23	4.39	4.84	3.80	4.03	3.45	2.89	2.79	1.94	1.09	1.06	.63	35.14
PINE & HARDWOODS	5.87	7.44	9.76	9.28	10.68	10.83	9.94	8.65	5.30	2.84	1.59	.63	82.81
	13.31		40.55				28.73				2.22		

FIG. 1-C GROWING STOCK EXPRESSED IN CUBIC FEET PER ACRE



	TOTAL VOLUME OF STEMS (ROOT COLLAR TO TIP) IN CUBIC FEET												TOTALS
PINE													
DESIRABLE	6.0	25.3	64.3	88.2	127.4	157.5	189.6	149.6	90.0	46.2	19.6		943.7
UNDESIRABLE	1.5	6.3	16.0	21.7	31.2	39.9	41.6	35.2	24.0	15.4			232.8
TOTAL	7.5	31.6	80.3	109.9	158.6	197.4	211.2	184.8	114.0	61.6	19.6		1176.5
HARDWOODS													
DESIRABLE	5.8	14.4	32.2	35.8	48.8	43.9	35.1	35.4	24.3	15.1	12.4	7.6	310.8
UNDESIRABLE	13.4	31.0	59.2	43.8	41.5	36.6	32.6	29.0	20.3	10.0	12.3	7.6	337.3
TOTAL	19.2	45.4	91.4	79.6	90.3	80.5	67.7	64.4	44.6	25.1	24.7	15.2	648.1
PINE & HARDWOODS	26.7	77.0	171.7	189.5	248.9	277.9	278.9	249.2	158.6	86.7	44.3	15.2	1824.6
	103.7		888.0				773.4				59.5		

FIG. 1-D SAWLOG GROWING STOCK EXPRESSED IN BOARD FEET PER ACRE



	BOARD FOOT VOLUMES OF SAWTIMBER PER ACRE						TOTALS
PINE							
DESIRABLE	816	772	462	243	104		2397
UNDESIRABLE	200	181	123	81			585
TOTAL	1016	953	585	324	104		2982
HARDWOODS							
DESIRABLE	104	134	111	77	68	44	538
UNDESIRABLE	96	110	92	52	68	44	462
TOTAL	200	244	203	129	136	88	1000
PINE & HARDWOODS	1216	1197	788	453	240	88	3982
	3654				328		

SEEDLINGS | SAPLINGS | POLES | SMALL SAWTIMBER | LARGE SAWTIMBER

LEGEND

PINE
- TREES OF DESIRABLE FORM
- TREES OF POOR FORM

HARDWOODS
- TREES OF DESIRABLE SPECIES AND FORM
- TREES OF UNDESIRABLE SPECIES AND FORM

maximum sustained production of high-quality timber. Many years will be required to remold the unmanaged forest to the pattern desired, but if proper attention is given to the economic requirements of commercial operations as well as to stand improvement, good management should prove profitable from the beginning and become increasingly lucrative as yields increase in quantity and quality.

The fact that growing stocks often are seriously deficient in quantity has led some persons to infer that complete cessation of cutting operations is a desirable way to build up growing stock. Unless the trees are well distributed and the stands extremely light, for example, under 1,000 board feet or its equivalent per acre, this idea is erroneous. Owing to the irregular distribution of timber in neglected forests, even light average stands include dense groups with surplus trees needing removal. All unmanaged stands contain numerous individuals too poor to continue as growing stock, and even well-managed stands always contain some trees of this kind, which are usually capable of yielding current income if cut, but which are of little value as future growing stock. It must be concluded, therefore, that the ax is the principal cultural tool in forestry and that, to grow good timber efficiently and rapidly, a regime of light and frequent cutting is an essential practice for nearly all stands.

The application of sustained yield can be insured only through correct cutting practices applied to definite units of known area and growing-stock conditions. Sustained yield of a sort is certain to result on each forest unit if each cut removes not more than will be replaced by growth before the next cut. In understocked stands—and these constitute over 90 percent of the forests of the South—the aim of sustained-yield management is to build up the growing stock by currently removing less volume than is added by growth. If possible, not less than 20 percent of the natural growth should be saved for this purpose. In the absence of abnormally serious fires, tornadoes, or insect epidemics, this reserve growth is not lost but is added to the capital growing stock and can be liquidated whenever desired. Like interest on a savings account, growth on wood capital accumulates at a compounded rate.

In placing unmanaged forest properties under sustained-yield management, a policy of light cuttings and short cutting cycles is desirable. Light cuts cause the least disturbance to the balance established in nature, and frequent cuts on the same area provide the means of promptly correcting some of the mistakes of previous cuts and of salvaging insect-infested and other trees lost through natural causes. These light cuts also provide for liquidating financially mature and over-mature trees and for thinning overcrowded stands. A light cut permits a much larger proportion of the accessible forest property to be covered when removing the allowable volume of cut (as determined by the growth on the whole property). Cutting cycles of 5 to 10 years are desirable in second-growth stands.

Most stands of second-growth southern pine are understocked in trees of sawlog size, and the building up of these larger diameter-classes is usually a prerequisite to increasing productivity of southern-pine lands. On the other hand, most stands are proportionately better stocked with natural regeneration, saplings, and pole-sized trees; cutting merely to increase the area available for these size-classes, therefore, is undesirable. In fact, cutting which would divert growth from the larger trees that will

be utilized within a comparatively short time to smaller trees that will have no value for many years, is not good management. But if the trees selected for cutting are distributed lightly throughout all merchantable diameter-classes, instead of taken chiefly from the larger sizes (as has been done commonly in the past), the distribution of timber will be shifted from smaller to larger diameter-classes. This shift is more rapid than can be inferred from the average figures of diameter growth because some trees, growing under favorable conditions, increase in diameter at a much greater rate than the average. Owing to this factor, where tree values are similar to those of a recent study, a 14-inch tree worth 41¢ in 1935 may become a 24-inch tree worth $11.42 by 1960 (end of a 25-year period). More significant in current operation is the upward movement of the whole growing stock, which insures at short intervals an adequate yield from each area.

Figure 2 illustrates theoretically how cutting in all merchantable diameter-classes builds up the growing stock in the larger sizes. The stand-structure diagrams illustrate the basal area per acre that it is estimated will be present at the beginning of 5 different cutting cycles. The first diagram shows the basal area per acre of the present growing stock as determined on 1,000 acres of second-growth loblolly and shortleaf pine and hardwoods in southeast Arkansas. It also illustrates proposed improvement cuttings to be made immediately in both pine and hardwoods in the present stand. The second diagram shows the estimated basal area per acre of the stand after 10 years of growth and also a proposed cut of 25 percent of the basal area in each diameter-class. The remaining three diagrams show the estimated growing stock at the end of 20, 30, and 40 years as well as cuts in both pine and hardwood amounting to 30 percent of the basal area in each diameter-class. These diagrams are purely hypothetical and do not represent results of actual measurements under sustained-yield management, but they are based on growth rates actually found in the timber on a 1,000-acre tract in Arkansas.

These diagrams indicate that the total basal area of the timber in the large-sawtimber classes will increase from almost nothing in the present stand to a fairly satisfactory stocking after 40 years and may include trees as large as 32 inches d.b.h. Although these diagrams may not represent the actual growth that will take place, they are fairly conservative in their predictions, and in a general way illustrate the shift in diameter-classes that may be expected when such cutting practices are followed. In the last diagram a suggested "normal" 4/ growing-stock distribution for the pine stand is indicated by a curve. This curve is theoretical and its height is arbitrary, but its form is based on the observed distribution of diameter-classes in European stands under intensive selective management for sustained yield.

If all trees to be cut are selected from the silvicultural point of view, progress in building up the volume and quality of the growing stock will be very rapid. Obviously, in any area operated under a given cutting cycle, the removal of crooked, rough, or otherwise undesirable trees—and

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4/ A normal forest is a standard with which one can compare an actual forest to bring out its deficiencies for sustained-yield management; an ideally regulated or organized forest; a forest with normal increment, age classes normal in size and distribution, and normal stock.

particularly of inferior species of hardwoods—will leave better trees to grow. For this purpose cuttings should extend currently throughout all merchantable diameter-classes, and it should not be necessary to shift future growth entirely to seedlings and saplings, from which growth can be harvested only in the distant future. Where pulpwood or other cordwood is utilized, light cuttings may be made in the pole-sized trees, removing only those individuals that will not develop into high-quality material. Less frequently recognized in cutting practice is the need for saving many well-formed, vigorous trees in the small-sawtimber group to grow into the large-sawtimber group, and within the latter group to select specimens, exceptional in quality and vigor, to grow into still larger diameter-classes. It is not fully realized by forest owners that most of the volume growth on large trees is on the relatively extensive surfaces of the merchantable portions of the stems; that because of the greater clear-lengths of the stems, most of this growth on the large trees is of high quality; that relative to the amount of ground space occupied, the growth on large trees is much greater than that on small ones; that the large trees are relatively immune from injury by fire; and that the cost of logging and milling per thousand board feet is much less for the large trees. For these reasons the size at which high-quality trees reach financial maturity is far greater than that now generally accepted as a basis for cutting and greater than that now commonly found in second-growth stands. For economic and other (e.g., social) reasons, production must be maintained, but practical cutting operations largely center around the decision of which stems to cut and which to leave. By pursuing a light cutting procedure, the growing stock can be built up in both volume and quality, and the level of the yield can thus be raised materially.

It is evident, however, that yields cannot be continued indefinitely without a satisfactory regeneration of the forest. In most places where shortleaf and loblolly pine forests are protected from fire, adequate pine reproduction may be expected to follow all types of cutting except the very light and the very heavy. In making very light cuts, reproduction is generally both undesired and unnecessary; while in making very heavy cuts, regeneration often fails because the source of seed is reduced severely. Although natural reproduction of pine usually fills openings made by removing <u>individual</u> sawtimber trees, under certain conditions this is not true, and it may be necessary to remove <u>groups</u> of sawtimber trees in order to stimulate regeneration. In the past, heavy exploitation of stands for pine alone left in many places a larger proportion of hardwoods, including many commercially undesirable trees, which, after several years of development, effectively prevent pine from becoming established in the understory or from making satisfactory growth. Studies have shown that girdling, which is effective in killing these worthless hardwoods, usually requires 1 to 5 man-hours per acre, depending on the number and size of trees girdled. Even in stands originally without numerous hardwoods, the heavy cutting of pine timber is often followed promptly by a rank growth of hardwood shrubs and trees to the apparent exclusion of all pine seedlings. Fortunately, on pine uplands this failure in the reproduction of pine may prove to be only partial, as in some cases numerous pine seedlings finally emerge above the brush, develop normally, and, when closely surrounded, even grow into superior trees because of the presence of hardwood associates. Nevertheless, the net result is commonly a deterioration of the forest, owing to the reduced volume of pine timber in the second-growth stands. Surveys have shown this condition to be prevalent over extensive areas now being protected from

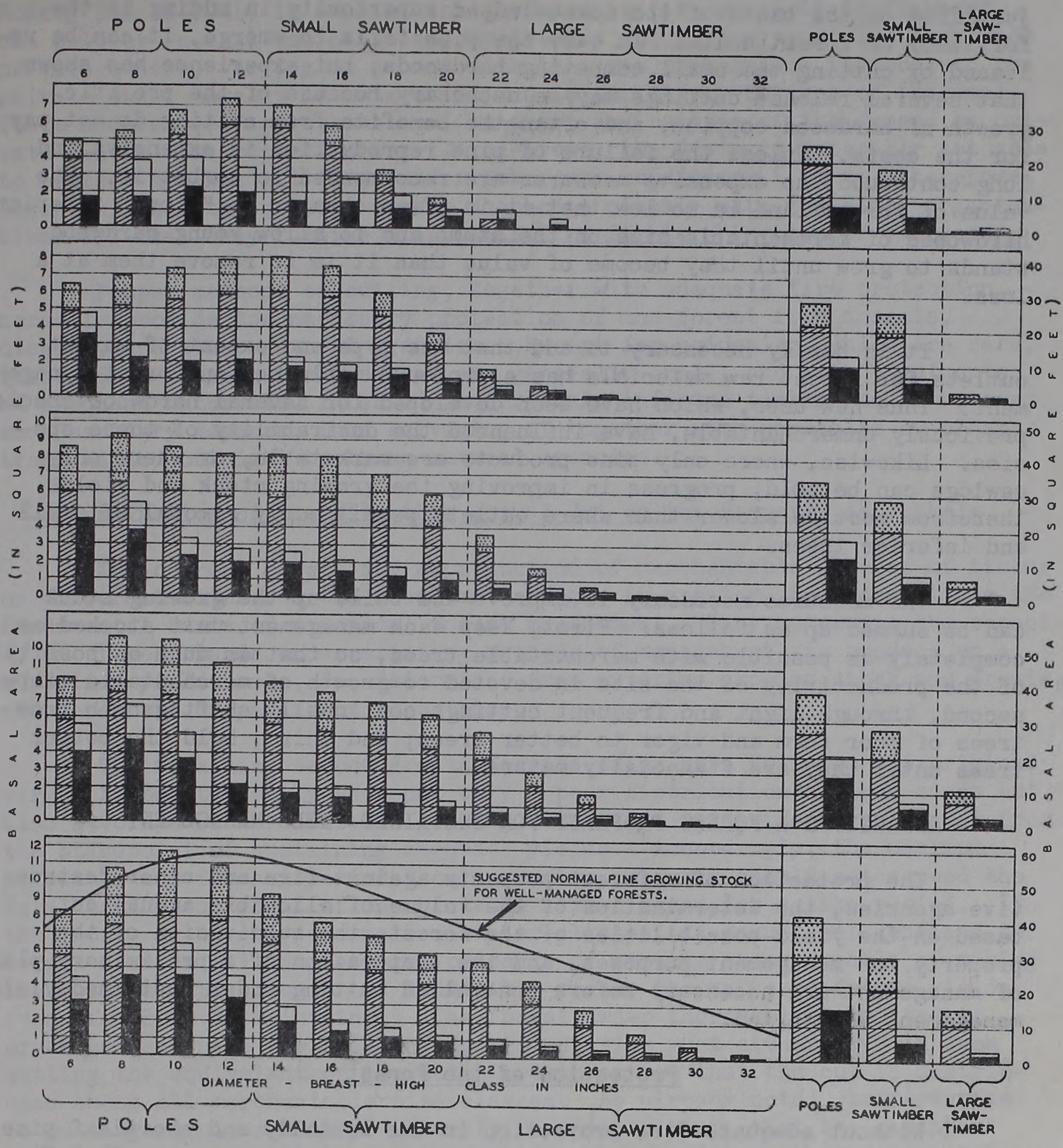
POLES
SMALL SAWTIMBER
LARGE SAWTIMBER
POLES
SMALL SAWTIMBER
LARGE SAW-TIMBER
6 8 10 12 14 16 18 20 22 24 26 28 30 32
BASAL AREA (IN SQUARE FEET)
SUGGESTED NORMAL PINE GROWING STOCK FOR WELL-MANAGED FORESTS.
DIAMETER - BREAST - HIGH
CLASS IN INCHES
PINE GROWING STOCK AFTER CUT
PINE GROWING STOCK CUT
HARDWOOD GROWING STOCK AFTER CUT
HARDWOOD GROWING STOCK CUT

FIGURE 2. - STAND STRUCTURE DIAGRAMS SHOWING PRESENT GROWING STOCK, PROPOSED IMPROVEMENT CUTTING OF PRESENT STAND, AND ESTIMATED GROWING STOCK AND PROPOSED CUTS AT END OF EACH OF FOUR 10-YEAR CYCLES; BASED ON A 20-PERCENT INVENTORY AND INTENSIVE GROWTH STUDY OF 1000 ACRES OF SECOND-GROWTH LOBLOLLY AND SHORTLEAF PINE AND HARDWOODS IN ARKANSAS.

fire. Marked increases in the hardwood component of pine stands cannot be justified on the basis of its acknowledged superiority in adding to the fertility of forest soils. In case the pine fails to emerge, it can be released by cutting the small competing hardwoods, but experience has shown that several release cuttings may be necessary because of the prolific growth of hardwood coppice, and often the benefits from cutting do not pay for the costs. Unless the failure of pine reproduction is extensive and long-continued, no expensive measures are recommended to combat it. The value of forest land is so low that it is often cheaper to "store" inferior hardwoods of merchantable size on the stump and to allow young hardwood stands to grow until they become of value than it is to remove them at a loss.

It is hardly necessary to add that the type and extent of market outlets for forest raw materials has a profound influence on forest management. Thus new uses, which have been developed for several hardwood species previously unmerchantable, have influenced the desirability of these species. Likewise, where only pine products are marketable, or where only sawlogs can be sold, progress in improving the growing stock and yields therefrom must be slower than where outlets permit early removal of small and inferior trees.

The measures necessary to improve and build up the growing stock can be summed up as follows: First, keep each management unit stocked as completely as possible with merchantable trees, so that as much as possible of the productivity of the site is devoted to growth of merchantable timber; second, through light and frequent cuttings continually shift growth from trees of poor form and vigor to better trees; and third, hold the better trees until they are financially mature.

ORGANIZING A FOREST PROPERTY FOR SUSTAINED-YIELD MANAGEMENT

The protection of a forest property against fire and other destructive agencies, the determination of the volume of allowable annual cut based on the yield possibilities of the forest, the subdivision of the property for management purposes, and the preparation of a preliminary plan of management are necessary before controlled cutting under sustained-yield management is started.

Protection of the Forest

Without adequate fire protection in the loblolly and shortleaf pine forest, management for sustained yield is useless, since uncontrolled fires often prevent natural regeneration, and destroy, or at least seriously damage, premerchantable or even sawtimber growing stock. Fire protection involves both the prevention of forest fires and their prompt detection and efficient suppression. Although various degrees of fire protection may be regarded as satisfactory, for the purpose of continued forest production, a reasonable goal limits the average area burned per year to less than 1 percent of the total forest area protected.

Where forest holdings are not well consolidated, this goal may be difficult for an owner to reach independently, but fortunately since forest production and fire protection are very widely recognized as essential to public as well as private interests, cooperative fire protection organized

under the State Forestry Departments has been legally recognized (Clarke-McNary law of 1924) in each of the southern States, where it is financed not only by Federal and State appropriations but also by contributions from private owners, varying in amount with the area protected. The cost to the private owner usually is between 2¢ and 4¢ per acre. Because of the small State and Federal appropriations, however, and because of the demand by private owners for protection over large areas, the State is generally not able to protect against all fires under emergency conditions. It is, therefore, essential that the private owners cooperate closely with the State organizations and that they furnish additional fire fighters in case of emergency.

Proper methods of cutting, together with adequate fire protection, normally provide the necessary protection of the forest from insects, disease, and other natural agencies. Except for epidemics, which are rare, losses from these natural causes are generally small, and with light cuts at frequent intervals, infested or seriously infected timber can be removed as a sanitary measure, thus salvaging it together with windfalls or other trees killed outright by these natural agencies.

Determination of the Allowable Annual Cut on the Property as a Whole

The current growth and reproduction of merchantable species of timber on different sites and the resultant changes in growing stock constitute the fundamental basis of practical forest management. They determine the capacity of "forest lands under existing methods of management" to produce on a sustained-yield basis, "as determined from existing growing stock and growth," and hence are of paramount importance.

The remaining second-growth forests which have followed the original virgin timber typically show not only a poor distribution of tree sizes but also a volume of merchantable growing stock that is decidedly subnormal from the standpoint of sustaining adequate yields. Accordingly, the maximum allowable cut for any period from an entire property should not exceed the total estimated growth of merchantable size-classes for a like period. If the growth is largely on small diameter-classes, an annual cut confined to larger classes will deplete the property of growing stock capable of making the most valuable growth and inevitably reduce the value of future yields even if volume be maintained. The forest owner thoroughly committed to practices adequate for building up productivity must either refrain from cutting the equivalent of the total growth or see that the cut is distributed among all merchantable size-classes. As already noted, conservatism in cutting requires another entirely reasonable step, that is, saving a certain percentage of the growth for necessary additions to the growing stock. Saving 20 percent of the annual growth over a period of 20 years should add from 30 to 50 percent (depending on the site) to the total present volume of growing stock and likewise to the subsequent annual growth and yield. If, at the same time, the diameter distribution of the growing stock is improved by continuous careful selection, as discussed hereafter, the value of the yield will increase much more rapidly than the volume. This program of reserving a part of the growth for permanent growing stock also permits more freedom in selecting timber for the current cut.

At first thought, it may seem that owners having sawmills or other plants depending on their forests for logs would be unable to restrict their cut if sustained-yield operations provided an insufficient volume of

logs, but with the advent of motor transportation, which makes timber accessible up to 25 or more miles from the sawmill, the log supply can generally be augmented by purchases and the volume requirements thus fulfilled. It should also be noted, however, that in order to avoid direct losses to the forest owner and to take advantage of good market conditions, it is imperative that the cutting budget decided upon permit reasonable flexibility from year to year.

Although light and frequent selective cuttings under conservative management may maintain certain yields on definite units of the property and eventually on the entire property, it is important to know as early as possible the volume of timber that can be cut annually without depleting the growing stock. In the early years of organized management, determination of the volume of allowable annual cut usually must be based on a preliminary estimate or inventory of the total merchantable growing stock and a predicted growth in merchantable volume for the property as a whole.

Despite the desirability of an inventory and determination of total growth, caution is necessary to avoid wasteful and unproductive expenditures for these purposes. The yields of southern pine can be changed so rapidly through good or bad practices that extreme refinement of yield calculations is wholly out of place until a definite and stabilized system of management is in effect. For this reason, it is better to be satisfied at the start with approximations to the volume of growing stock and rate of growth and to concentrate expenditures on development of cultural cutting practices that will build up production. Many forest owners have timber cruises, which, although usually lacking in details as to size and quality of timber, suffice for preliminary surveys of growing stock.

If information from recent cruises is not adequate, the cheapest and most accurate method of obtaining the minimum information needed is by a line-plot survey conducted by a competent technician. This consists of running parallel compass lines at regular intervals to gridiron the property and taking accurate measurements of all trees of merchantable size on small circular plots (usually 1/5 or 1/4 acre) at regular intervals along the lines. The spacing of the lines and plots (often decided largely on the basis of available funds) depends on the size of the property, the uniformity of the timber stands, and the degree of accuracy desired. On forest properties composed chiefly of second-growth stands of pine, the spacings shown in table 1 will generally be satisfactory for the restricted purpose here contemplated.

Table 1. Suggested spacing of lines and plots for surveys on properties of various sizes

Size of forest property	Interval between lines	Interval between 1/5-acre plots		Portion of total area sampled	Approximate number of plots
Acres	Miles	Chains	Feet	Percent	
100,000	2	10	660	0.125	625
50,000	1	10	660	0.25	625
25,000	1	5	330	0.50	625
10,000	1/2	5	330	1.00	500
1.000	1/4	2	132	5.00	250

Note that, unlike the 10- to 20-percent inventories sometimes used for locating and mapping timber types and stand conditions, the area actually covered in sampling is small, indicating a relatively inexpensive cruise. From the results obtained, the average number of trees, the basal area, the volume in cubic feet, and the volume in board feet per acre all can be sufficiently well determined. Totals for the entire property are obtained, of course, by multiplying the results for the average acre by the total number of acres. It should be emphasized, therefore, that results based on the field work as set up in the above table will be sufficiently accurate only if applied to the entire property. Obviously these non-intensive timber cruises will not show the amount of growing stock on smaller tracts such as sections or other small units of management. It must be remembered, however, that the sole object of such a preliminary survey is the blanket determination, within reasonable limits of error, of the aggregate timber volume on the forest, to be used as a basis for arriving at the allowable gross volume to be cut currently from the whole property.

Owners wishing to place unmanaged forest properties under sustained-yield management seldom possess accurate information on the growth rates of their timber by species and size-classes. Consequently, in order to determine the approximate current yielding capacity, on which to base the volume of the allowable annual cut, growth studies are generally necessary. Volume growth naturally varies with the productivity of the site and with the amount and kind of growing stock. On better sites, and in second-growth loblolly and shortleaf pine stands as now stocked, annual growth amounting to 100 - 400 board feet per acre is common.

The rate of diameter growth is by no means stable in typical young understocked forests, but tends to decrease progressively as the stands gradually close in, since competition between growing trees increases with their size. This natural deceleration of diameter growth can, and usually should, be reduced or eliminated by applying the cutting practices recommended in this paper. Such cutting may automatically raise the average growth rate merely by removing slow growers, regardless of any acceleration in the growth rates in reserved trees. The maximum possible rates of diameter growth, however desirable on clear-stemmed, individually selected crop trees, are not desirable for the reserved stand as a whole, because the fastest diameter growth is commonly found only on commercially undesirable,wide-spreading trees of exceedingly poor form and quality. Therefore a moderate average rate of diameter growth permits maximum yields in value of stands. With equal rates of diameter increase, a large tree produces much more wood than a small one, but because of their size, the percentage rate of volume growth is less for the larger and more valuable trees. Accordingly, the existing volume growth of stands should be increased primarily by increasing the growing stock or basic wood capital rather than by attempting to increase materially its percentage rate of increment.

The annual volume increment in shortleaf and loblolly second-growth stands commonly varies from 4 to 9 percent of the growing stock, being less on poorer sites and in the heavier, better-stocked stands. Some timber owners have attempted to estimate the percentage of growth merely by assuming that the lands and stands to be managed are similar to others of known capacity for growth. Such gross approximations, which are unreliable at best, and which will be found inadequate for most owners who seriously

contemplate forestry, should never be trusted until checked against growth data gathered from the timber property itself.

As has been noted already in the preliminary determination of growing stock as a basis of yields, it may be justly held that refinement in the first studies of growth is unwarranted, because the amount of such growth obtainable under management in the South can be changed readily and materially. Nevertheless, rates of growth can affect yields so vitally that they demand serious consideration; and forest owners should have some knowledge of general principles and methods of growth study, even though the more accurate determinations be tasks for competent foresters.

A common procedure in forecasting current growth in merchantable volume a decade in advance is to contrast the volume of timber stocks as computed from existing stands and from the stands as they are predicted to be at some future time, thus estimating the probable net increases in volume. If the survey used for estimating the volumes of the total timber stands covers the entire forest property systematically, it provides an excellent opportunity to study the growth of timber. This can best be done by measuring the radial growth during the past 10 years on all of the merchantable trees found on small circular plots, e.g., 1/40 or 1/50 of an acre, within each of the larger plots used to record growing stock. Also all trees of specified premerchantable size-classes found on these small plots and expected to grow into merchantable size during the next 10 years, should be sampled to determine their radial growth, which can be measured on a core of wood extracted by an increment borer.

The method of forecasting a future forest stand is of interest. A slight reduction is made in present numbers of trees to allow for expected mortality during the period.5/ The approximate movements of trees out of each class and into certain larger size-classes is then tabulated. This must be done not only for each merchantable diameter-class but also for those premerchantable sizes expected to become merchantable within the decade. This so-called "in-growth," which is a relatively large item in thrifty second-growth forests, often amounts to 30 to 50 percent of the total volume growth. The forecast rests upon the rates of diameter growth found typical of the various sizes of trees, but it may employ only averages read from curves, thus disregarding the intricate dispersion of growth rates of individual trees. Also growth rates of wood as measured inside the bark require a slight correction to make allowance for increases in bark thickness. The future stand could be forecast very simply by accepting these average rates of wood and bark increase as the growth of <u>all</u> trees in a given size-class. A better way, however, is to recognize the approximate effect of dispersion of growth rates within size-classes. This can be done, even without a true measure of such dispersion, by relying on the following hypothesis of tree movement: The number of trees which grow from a smaller into a larger diameter-class bears the same relation to all trees in the <u>smaller class that the average growth rate (in inches) for that smaller</u>

5/ No precise way of judging mortality rates is known, but in well protected stands of southern pine the loss in merchantable growth over a short period like 10 years is usually quite small. Furthermore, where dead trees can be promptly salvaged, none of the past growth is sacrificed, the loss being confined to that remaining portion of potential future growth not automatically transferred to desirable neighboring trees.

class bears to the diameter-class interval (in inches). Thus with a 2-inch diameter-class interval, the process works out as shown in table 2.

Table 2. Approximate hypothetical change of distribution in size-classes of trees of varying growth-rates

Growth in d.b.h.	Movement factor 1/	Trees moving up two classes	Trees moving up one class	Trees remaining in present class
Inches		Percent		
3.8	190	90	10	0
3.0	150	50	50	0
2.4	120	20	80	0
2.0	100	0	100	0
1.0	50	0	50	50
0.6	30	0	30	70

1/ Derived in each case by multiplying the growth in inches by 100 and dividing by the class interval in inches. Thus for these 2-inch classes the movement factor is obtained by multiplying the growth figure by $\frac{100}{2}$ or 50.

The number of trees moving ahead is then obtained by applying these percentages to the number of trees present in each class. The total growth estimated for the property as a whole during the 5- or 10-year period is the difference between the volume of the present stand and the volume of the predicted stand.

This method of predicting growth rests upon two assumptions: (1) the variation of tree diameters is uniform within a given diameter-class, providing a nearly equal representation of all sizes within the class, and (2) a constant rate of increment—represented by the average for a given diameter-class—maintains this uniformity as each successive group of trees grows into larger diameter-classes. Since these assumptions of uniformity in size distribution and constancy of growth rates within classes are incorrect, inaccuracies resulting from the use of this method may be expected. Figure 1-A shows that the trees in the stand illustrated are so distributed as to form a J-shaped frequency curve. In such stands, because the smaller trees in each class are more numerous than the larger ones, the errors resulting from the first assumption would be positive. In other words, when using this method to predict the future stand, too many trees are moved forward from each diameter-class; this results in an accumulation of small errors and a consequent exaggeration of volume growth. The total error might be appreciable if the development of saplings and pole-sized trees were being forecast, because of the relatively great abundance of the smaller trees in this portion of the growing stock. For the sawtimber portion of stands, however, like the one illustrated in figure 1-A, the error in the final result may be well within permissible limits of total error in forecasts of this kind.

Further refinement of method, to allow for variation in growth rates, requires that the timber cruisers bore a larger number of trees. Enough samples of wood and bark growth must be obtained to permit computation of the percentage of trees which remained in their initial class and the

percentages which moved up one or two classes during the previous 10 years. Such information worked out separately for each diameter-class provides a much truer picture of actual tree movements and permits of more precise forecasts.

One way of applying this percentage method to a single diameter-class may be illustrated as follows: Suppose, for example, predictions are desired for growth during a period of 10 years of the trees in the 14-inch diameter-class, if the average acre bears 12.18 trees, of which 12 are expected to survive, and if one-sixth remain in the 14-inch class, two-thirds move into the 16-inch class, and the other one-sixth move into the 18-inch diameter-class. The present volume of these trees is 12.18 x 154 (board-foot volume of 1 tree) = 1876 board feet. In 10 years these trees attain the following volumes:

	Board feet
the 2 trees remaining in the 14-inch diameter-class (154 board feet each)	308
the 8 trees in the 16-inch diameter-class (227 board feet each)	1816
the 2 trees in the 18-inch diameter-class (308 board feet each)	616
Total volume at end of 10 years	2740
Volume at beginning	- 1876
Growth of 14-inch diameter-class during 10 years	864
Average growth of 14-inch diameter-class in 1 year	86.4

After treating each diameter-class in this manner, including the larger premerchantable classes, the figures may be added to show the volume growth expected from the average acre of the forest.

In view of the obvious need for economy in preliminary studies of growth, the superiority of the more accurate percentage method may be questioned because of the much larger number of trees that must be sampled by boring. Increased knowledge of the dispersion of growth rates in the forest, however, may be useful in other ways, particularly in the selection and development of crop trees by cultural methods.

Subdivision of the Property for Management Purposes

Actual management for sustained yield must be applied to definite units of known area and growing-stock conditions. Before cutting is started, a forest should be subdivided into blocks and compartments for administration and management. Blocks usually exceed 50,000 acres in area and are used to subdivide large properties for better administration. Compartments are the real units of management, and simple but adequate accounts of changing growing-stock conditions and yields should be kept for each.

Where rectangular public-land surveys exist, some owners keep all records by legal subdivisions of 40 acres each. This, however, leads to an unnecessary multiplicity of records; and the quality of the records, with

the possible exception of those for small properties of not over 5,000 acres, is certain to suffer. In other cases the land owned in each legal section is taken as the unit area for making contracts and records. This has advantages where ownership readjustments are still taking place. Where stable ownership of considerable areas has been attained, units of 500 to 2,500 acres, bounded by a combination of roads, streams, and land lines, not only may be handled very easily in all forest operations but also will reduce the number of records to a minimum. It may be mentioned that a well-devised road system is necessary if the lowest costs possible are to be attained by motorized logging; and if this road system can be surveyed before cutting begins, it is desirable to use some of the primary roads, even though they are not yet constructed, as the boundaries of compartments. All compartment boundaries should be plainly marked on the ground and accurately mapped.

It is advantageous to segregate hardwood bottomlands in separate compartments, but it is not necessary that pine stands be thus separated by stand conditions. Formerly it was believed that management subdivisions should, so far as possible, contain areas all in the same age-class, but experience does not justify giving any weight to this factor in irregular forests. Because of the varying stand density and the consequent range in tree sizes, much timber may be of even age but decidedly uneven in development and character. This applies both to individual trees and to groups in the stand. In consequence, one portion of the area may become ready for regeneration before others, and thus the uniform character of even-aged forests is broken up under selective timber management. After some years of management, all pine stands will be composed of trees of many sizes and age-classes; and compartments that were established to include certain stand conditions will lose their distinctive character. Since compartments are the units of management, they should be very carefully selected for permanence and with the definite purpose of establishing an adequate but simple system of permanent records.

Preparation of Preliminary Management Plan

European forests and those of other countries where forestry is well established are almost invariably managed in accord with written plans, which prescribe the total amount of the annual cut, allocate the cutting to the various devisions of the forest property, and prescribe other operations usually in a rather rigid manner. It must be remembered, however, that these rigid plans are generally for forests which have been under management and for which adequate records of the yield and growing stock have been kept for a long time; they therefore represent reduction of this long experience to a written form, as a guide for future management.

As American forests have not been subject to sustained-yield management for any long period, the attempt to make plans of this nature even for public forests has been none too successful. Owing to the rapid movement of the business cycle, to changing standards in utilization, and to other factors, it has generally been found that detailed recommendations to be carried out from year to year form more of a hindrance than an aid to forest management. No plans that reduce the financial returns from the forest by too strict limitation of the cut when prices are high, or by prescribing continued marketing of products when they are low, can be considered a real success. Sustained-yield management does not preclude

sufficient flexibility in the annual cut to permit the forest owners to realize on a good market by cutting more of the growth and to avoid poor markets by cutting less of the growth. The sound rule for the forest manager is to "save growing stock in bad times, and save money in good times," so that the business is equalized and stabilized throughout the years. Money saved in good times can be used in bad times to make necessary forest improvements in lieu of cutting timber to create employment.

The type of management plan required, therefore, is one with a flexible application. At the beginning such a plan may consist of a careful collection of all pertinent and accurate data regarding stands, market outlets, and other available information; a mapped compilation of all available ownership data, compartment boundaries, transportation facilities, drainage lines, and forest types; and a statement of policy, which may include such items as the following:

1. Each periodic cut shall aim (a) to remove trees less valuable for further growth, including, so far as possible, the insect-infested, diseased, and crooked trees, and (b) to save for the reserved stand, vigorous, clear-stemmed trees in order to improve the quality of the growth.

2. The total volume of the periodic cut in any forest division shall be small enough so that the reserve growing stock can restore by growth during the ensuing cutting cycle as much or more volume as was removed (automatic sustained yield).

3. Light and frequent cuttings shall be practiced wherever possible.

4. Adequate records of the yield from each compartment and of the reserve growing stock left after each cut shall be kept as a basis for future planning and management.

The records of changes in growing stock and yields for each management subdivision are designed to register the continuing experience of management and thus form the basis for progressively more accurate planning as time goes on. With such a flexible policy of management in the hands of capable managers, constant advance can be made.

FORESTRY PRACTICES UNDER SUSTAINED-YIELD MANAGEMENT

All of the foregoing is explanatory or preliminary to the actual forestry practices necessary to derive satisfactory current returns from forest holdings, combined with continuous improvement of the forest property. The organization for protection against fire and other destructive agencies, the determination of the allowable cut, the subdivision into management units, and the preliminary management plan all apply to the property as a whole. From this point on, management is applied to definite units of known area, designated as compartments (see page 18).

It is in the selection and cutting of trees and the management by compartments that most of the budget provided for forest management should be expended, because better and less expensive methods of extracting timber from the forest and of delivering it to the mill or market are part and parcel of good forest management. Thus if the field budget is properly expended, it will save management expenses of equal or greater magnitude, such as the

unnecessary inventories already described.

The first steps towards sustained yield are: to stop indiscriminate, wasteful uses of immature timber; to eliminate unprofitable size-classes from the sawtimber cut; and to seek self-supporting outlets for surplus and inferior elements within smaller size-groups. All of these measures increase revenue; at the same time they conserve existing capital and pave the way to increased productivity and to correspondingly increased values in the future. Therefore, good forestry practices, inasmuch as they are the sole preventive of many unnecessary losses of current income and capital values, reduce expenses rather than increase them.

Selecting Areas to be Cut

After the total allowable cut has been determined for the property as a whole, the next step in forest management is to decide upon the order in which compartments will be cut. Although this order must conform to good logging practices, which reduce costs to the minimum, it should not be rigidly binding, since changes in market conditions may necessitate changes in the volume of future annual cuts and also in the nature of the materials to be cut. It is, therefore, advisable to designate the areas for cutting only 1 or 2 years in advance rather than for 5 or 10 years.

Each compartment, except those without sufficient merchantable timber to make logging financially feasible, should be cut lightly at intervals of 5 to 10 years. Because of the relatively flat topography and the well-developed system of public roads the timber on most forest properties in the South is readily accessible for truck logging, but a well-planned system of private roads on the property is necessary if the lowest logging costs are to be attained and if logging is to be carried on during the rainy season. Selective cutting of 1,000 board feet or more per acre is generally recognized as feasible, and studies of truck logging have shown that as little as 500 board feet per acre can be removed without increasing logging costs appreciably. With markets for pulpwood and fuelwood now established in many parts of the South, cutting of stands for these products is common and profitable.

The cut during the first year of management should include (within economic limits) any compartments with dangerous insect infestations, with windfalls, or with trees severely damaged by recent forest fires. It should also include (within limits of the allowable cut, computed as explained in the preceding chapter) those compartments bearing the greatest volumes of financially mature (or overmature) timber as well as those younger stands seriously in need of improvement cuttings because of overcrowding or other conditions unfavorable to growth and future yields of high-quality material.

Intensive and costly surveys are not necessary in order to locate those compartments in need of immediate cutting. Practically every operating company has information as to approximate volumes and locations of merchantable timber on its holdings. Recent purchasers of timberland undoubtedly have this information. Logging superintendents and land surveyors usually are familiar with timber conditions and often have made maps giving estimates of volumes by definite areas. By calling upon all available sources of information and through close cooperation with the logging division, the

forester, who should have the responsibility for selecting the compartments for cutting, and who should be familiar with all parts of the property, can plan the cut so as to make logging economical, and at the same time cut those compartments which are most urgently in need of cutting.

Selecting and Marking Timber to be Cut

Often the initial step in better forest management has been the issuance of instructions to workmen regarding the diameter limits of trees to be cut in selective cuttings. This may bring about minor improvements over old practices, but the results are invariably inadequate, because the timber to be cut has not been properly selected. Selection of timber for cutting is of primary importance both from the marketing standpoint, and from the standpoint of the reserve stand, which determines the production rates of the immediate future. Proper selection is, therefore, the heart and foundation of good management practice; it is not obtained from arbitrary size limitations and should not be given secondary consideration. Real improvement of cutting methods, therefore, demands that every tree be marked before cutting is allowed. Except in the case of the owners of small areas, who may do this work personally after studying the problems involved, marking should be carried out only by, or under the supervision of, a competent forester.

Selective cutting is a common term which is used to include all types of tree selection, whether for thinning in young stands, for making improvement cuttings in stands burdened with inferior species or individual trees, or solely for marketing. From the economic standpoint, it is most desirable to cut large trees at the time of their financial maturity, which is defined as the time when the individual tree or stand will no longer make an economically satisfactory increase in volume, quality, or price. By the same definition, financial maturity has arrived for surplus trees of any size which will not earn satisfactorily if left standing. In second-growth southern pine stands, financial maturity has seldom been reached by the larger and better trees, but it has generally been reached by large numbers of surplus trees in young stands, by inferior species of hardwoods, and by the rougher and more defective sawtimber trees of all sizes.

Another consideration is the minimum size of tree that will pay its way. In cutting pines for pulpwood, the economic minimum size is about 6 inches; while for lumber, operators of the larger mills find that a pine 13 inches d.b.h. is ordinarily about the smallest tree that will yield lumber of sufficient value to yield a profit over the costs of production. Operators of small mills, however, can often cut smaller trees without financial loss. For hardwoods the minimum size for profitable handling is usually somewhat larger than for pines. Frequently, however, cutting practices will be determined by manufacturing or other market requirements and by the financial needs of the forest owner. The marking program should, therefore, be one that removes gradually the inferior elements of the stand, taking only as many of the larger and better trees as necessity requires. In other words, a sound marking policy must consider both the cultural improvements of, and the economic returns from, the forest property.

So many ways exist in which to improve or impair the stand by selective processes that only certain aspects can be touched on here, in addition to what has already been said under "Improvement of growing stock" (page 5). It is very difficult to prescribe effective marking rules which can be applied to

the great variety of conditions found in irregular second-growth stands of loblolly and shortleaf pine and hardwoods. No guide to marking procedure can be of any practical use unless it is worked out in the woods and is based upon the actual conditions existing there. This means that any man doing effective marking must be one of seasoned judgement who knows the quality and value of timber products that can be produced from various species, sizes, and types of individual trees; who is able to recognize the thrifty and healthy individuals; and who understands what environment constitutes optimum growing conditions for pines and hardwoods. This does not mean that intelligent and alert men who are not technically trained cannot be taught to mark properly, but it does mean that a capable and experienced forester is essential for training and supervising these men and for solving new technical problems as they arise.

The objective in marking the allowed annual cut should be to leave the stand in the best condition possible for future growth by reserving financially immature trees and at the same time to make the current operations yield some profit. Merchantable trees to be marked for cutting may be classified, beginning with those to be removed first, as follows: (1) pines and hardwoods infested with insects or seriously infected with fungus diseases; (2) trees which will produce little or no volume growth and which probably will not be present at the time of the next cut, including badly suppressed trees, leaning trees, and trees with bad fire scars; (3) poor-quality trees that because of crook, short body, or limbiness will produce only growth of low quality; (4) overcrowded trees in dense stands that are seriously retarding the growth of better trees; (5) inferior species such as black jack and post oak, red maple, and other hardwoods that have a very limited market as sawtimber; (6) other financially mature and overmature trees; and (7) when cutting is absolutely necessary to satisfy the financial needs of the forest owner, trees approaching financial maturity. Where necessary to choose one of several trees, the one whose removal will result in more uniform spacing or in maximum improvement of the growing stock should be marked. Although white and red oaks are very valuable species on many sites and although other hardwoods with clean, sound, marketable logs may also be reserved, in general pines should be left rather than hardwoods.

The amount of the cut on a given compartment must be strictly limited to prevent further impairment of already deficient growing stock and to insure a minimum of interference with current growth. This amount depends upon the volume and character of the growing stock, the productive capacity of the site, and the length of the period before the next cut. Preferably, no more than 25 to 35 percent of the volume of the growing stock should be removed from a compartment at any one cut, but this usually means heavy cutting in some spots and lighter cutting in others. On fairly good sites, where the annual growth amounts to about 6 percent of the total volume of the sawlog growing stock, a cut of 25 percent of this growing stock usually can be restored by growth within about 5 years; likewise, a cut of 45 percent of the sawlog growing stock can be restored in about 10 years. If 20 percent of the growth in each case is reserved and added to the growing stock, the cut for the 5-year cycle should remove only 20 percent of the total sawlog growing stock and for the 10-year cycle only 35 percent. Skillful selection of the trees to be cut not only should increase the quantity of the growing stock but also should improve the quality and distribution of size-classes in the stand.

Controlling Cutting Operations

Because their contribution to forest productivity is not commensurate with their costs, it has been recommended that expensive general inventories be avoided. The savings thus made should be available for careful determination of the growing stock and the allowable cut on each compartment and for controlling this cut.

The total cut, as stated above, should generally not exceed 80 percent of the net growth for the next cutting cycle. In its simplest terms, the net growth on a compartment is the difference between the volumes of merchantable timber at the beginning and end of the cutting cycle. For the first cut, however, no records of stands 5 or 10 years ago are available for comparison with present stands in determining net growth. It will therefore be necessary to accept, as a rough guide for marking, a definite percentage of the total merchantable growing stock as the allowable cut, basing this percentage upon growth and stand data collected in the preliminary survey of the whole property. The forester in charge of the marking, however, should be free to use his expert knowledge and best judgment in raising or lowering this percentage, his decision being based upon actual stand and site conditions on the area being marked.

Since in marking sawtimber to be cut, all of each compartment must be covered by the marking crew, very little extra expense is involved in tallying by diameter-classes, major species-groups, and (possibly) quality classes the sawtimber trees marked for removal and also those trees (over 9 inches d.b.h.) reserved for further growth. A complete inventory of this nature is the most effective means of controlling marking.

The marking and field recording is performed by 4-man crews, in each of which an experienced leader directs the marking and records inventory data as called out by two markers who must be competent woodsmen and who should have sufficient education to qualify later for crew leaders. The marking which is done with white or other bright-colored paint, is greatly facilitated by using hand-pressure (grease) guns capable of projecting a fine stream of paint to about 20 feet. The fourth man runs the compass, delimits the marking strip, and makes a map showing drainage, transportation facilities, and forest conditions. The crews should be directed by an experienced and capable forester. Between 40 and 80 acres of second-growth pine can be marked, inventoried, and mapped by an experienced crew in a day, the cost usually falling below 10¢ per M board feet of cut. With a field inventory taken in this manner, it is possible for the leader to check constantly the percentage of trees within each diameter-class marked for cutting and thus keep the marking within prescribed limits. At the same time a very accurate inventory is obtained of the stand reserved for future growth.

It is from this reserved stand that the cut at the end of the next cycle (5 to 10 years later) will be made. Unless the compartment is well stocked, this cut should again reserve at least 20 percent of the net growth to add to the growing stock. The volume of this net growth can be obtained by taking the second complete inventory, computing the volume of the merchantable timber (over 9 inches d.b.h.) just before cutting, and then subtracting from this volume that of the reserved stand inventoried at the time of the last cut. It is not necessary that this second inventory be made and the allowable cut determined before the marking for the second cut

is done, but, as was the case for the first cut, the marking and inventory should be done at the same time, thus making it unnecessary to cover the same ground twice. Marking before the determination of the allowable cut may result in cutting a little too much or, on the other hand, in reserving somewhat more timber than is necessary. With skilled crews experienced in marking the same type of timber on other parts of the property, the volume marked for cutting can be made to approximate the volume of growth, or a certain percentage of it, if some growth is reserved. After the inventory of marked and of reserved trees has been completed, the discrepancies between volumes of growth and cut can be computed. A study of these discrepancies will enable the leader of the marking crew to achieve greater precision in marking and to approximate the desired cut more closely when marking trees in other compartments.

It is a relatively simple office task to make a permanent record for each compartment of the results of the tree inventory by diameter-classes and major species-groups under three headings, namely, the stand before cutting, trees marked, and trees reserved. The basal area and the sawtimber volume should also be computed and recorded.

In addition to the records based on the inventory, the volume of sawlogs, cordwood, etc., as derived from log-scaling or other measurements used in dealing with contractors, transportation companies, and purchasers of forest raw material, should be recorded for each compartment.

It is clear that this simple record system can be operated with a minimum of effort and at a very low cost and that, under effective business management, it can be maintained indefinitely. Thus, over a period of several cutting cycles, experience can be accumulated gradually and made to produce both increasing volume yields and increasing financial returns. An effective aid in utilizing such experience is graphic representation of the basal-area figures for the stand before cutting, of the cut, and of the reserve stand at the end of each cutting cycle on the average acre of any compartment (see fig. 2). As these diagrams accumulate, they will indicate graphically any marked changes in volume or in diameter-class distribution, whether for the better or worse.

Improving Young Stands by Cutting

The building of many new pulp and paper mills is establishing markets for pulpwood throughout most of the South. The low price paid for pulpwood, however, should discourage the good manager from selling his stumpage for this product if his timber has a present or a potential value for poles, piling, or sawlogs, since stumpage suitable for these higher-grade products generally brings a much greater price.

If there are ample outlets for pulpwood and other cordwood materials, it is obviously a simple matter to include in cutting operations as many surplus trees from the pole group and as many inferior trees in all timber classes as desired; then progress in improving the growing stock may be rapid. Over much of the South, where lack of a market inhibits removal of small or inferior hardwoods and a market for pine pulpwood is not yet available to all forest owners, often a slow rate of stand improvement must be accepted. Although establishment of more paper mills and the careful development of local fuelwood outlets may assist materially in relieving

forest stands of these elements, it is inadvisable to mark heavily even in the smaller size-classes or among the inferior trees and species, except in spots where regeneration is definitely needed and can be obtained from favorable species.

The cutting of pulpwood or other cordwood materials is generally a distinct operation from the logging of sawtimber and should follow such logging immediately, in order to utilize the tops of felled sawtimber trees while they are still acceptable to paper companies and other purchasers. At the same time that these tops are utilized, standing trees severely injured in logging, and trees whose removal will improve the quality and also the spacing of the residual stands, should also be cut for pulpwood or other cordwood products.

In dense young stands, such as often come in on old fields, and also in second-growth stands which will not be cut for sawtimber for several years, thinnings and improvement cuttings for pulpwood and other cordwood material are desirable to improve the quality and reduce the density of the growing stock, and to obtain a current income to help meet taxes and the costs of administration and protection, thus lessening the need for heavy cuttings in sawtimber. This permits the larger size-classes to be built up more rapidly and hence hastens the time when a large proportion of the growth will consist of merchantable material of high quality.

The cutting in each compartment for pulpwood and other minor products from pole stands and from inferior trees must not be left to the discretion of the cutters, but each tree to be cut should be first marked by a skilled and experienced man; one man, using a hand-pressure (grease) gun to spray paint on trees to be removed, is probably most economical. Generally in pole-sized timber it is not necessary to tally either trees marked or trees reserved, but the same principles of tree selection that are used in marking sawtimber apply in marking cordwood material, which can usually be marked at a cost of less than 5¢ per cord of material cut. In making thinnings, usually the largest trees, which are rough and hence poor potential sawtimber, the badly suppressed ones, and many others whose removal is necessary to obtain the proper spacing of the reserved-crop trees, are marked. In improvement cuttings, growth is shifted to high-quality trees by removing the diseased, crooked, and other undesirable trees. In all cases where merchantable material is removed, marking should be conservative, and only those trees should be taken which will not increase in volume, quality, or value at a satisfactory rate, since it should be remembered that the small trees of the present must supply the crop trees of the future and since every effort should be made to produce only high-quality, valuable trees.

FINANCIAL POSSIBILITIES OF SUSTAINED-YIELD MANAGEMENT

Profitable Cutting Operations

The first requisite of good management is that the timber removed shall yield a reasonable margin (preferably a wide one) of returns over costs. Under selective management the financially mature timber is removed first and the forest is brought gradually to a high state of productivity by eliminating the least productive part of the growing stock. All of the growing stock contributes to growth, but the more valuable timber is the chief source of the current cut. The average return per M board feet of the cut

therefore far exceeds the average possible conversion value per M board feet of the total merchantable growing stock. This means that current earnings on the realizable capital is far in excess of the current growth-rate; and it is therefore essential for profitable management that the larger trees and higher qualities be conserved so that the later cuts can include a large proportion of timber with values above the average of the growing stock. Thus, by maintaining the growing stock, there are no depletion costs to be charged off against the annual cut. Furthermore, by maintaining a fair degree of density in the merchantable size-classes, diversion of an excessive portion of the productive capacity to surplus regeneration and premerchantable timber, such as followed the heavy cuts in virgin timber, can be avoided.

Studies made in 1935 by the Southern Forest Experiment Station of conversion values of trees by sizes and major species-groups show that the values per M board feet of larger trees is much greater than for smaller ones. They also show that logging, milling, and other production costs per M board feet are considerably less for large trees than for small ones. The stumpage conversion value per M board feet for second-growth shortleaf and loblolly pine, that is, the difference between the selling price of lumber and all costs of production, was $1.43 for 12-inch trees, $4.73 for 16-inch trees, $8.00 for 20-inch trees, and $11.42 for 24-inch trees. It was also found that selective logging with trucks was feasible without constructing special roads except in very wet periods, and that a cut of as little as 500 board feet per acre increased costs per M board feet very little over that of heavier cuts. Evidently management that after the first cut removes mostly the larger trees, which are financially mature or nearly so, yields greater profits than clear-cutting, which necessarily must include some trees utilized at a loss. Studies in second-growth stands have further shown that the percentage of the higher grades of lumber resulting from selective cutting were not much less than those obtained from clear-cutting of virgin timber, because, even under the best management, only a small percent of the volume cut need come from defective, crooked, and otherwise low-quality trees, removed a few at a time to improve the stand. Except in open-grown old-field stands, the quality of the trees in second-growth stands is surprisingly high, but the percentage of trees in the large-sawtimber classes is small.

Integrated Utilization Helps Sustain Yields and Profits

Integrated utilization, which provides for the highest and most profitable use of each tree and all portions of each tree, is an important factor in increasing returns under good forest management and should be developed as far as markets will permit, inasmuch as by this type of utilization the largest possible number of workers is employed and the largest profit returned to timber owners.

In the shortleaf and loblolly pine region, several large lumber companies are practicing integrated utilization. Their primary products are high-grade lumber and timbers cut from choice logs, and lower grades of lumber and timbers from poorer logs. The lower-quality top logs of pine are profitably cut into lumber by some companies, by using short lengths in remanufacture, while other companies not equipped for such a high degree of utilization, often find they can make more profit by cutting top logs into pulpwood. Pulpwood is sometimes cut from tops of felled sawtimber trees, but a very small yield or none at all is obtained from the larger trees because of the difficulty of splitting and the high cost of lopping off the large

limbs. Pulpwood is also cut from trees removed in thinnings and in improvement cuttings. For tops and inferior stems of hardwoods there exists a limited market as chemical distillation wood and fuelwood. Some pine trees are also cut for wood-preserving plants that treat poles, piles, ties, and fence posts.

Studies of integrated utilization of shortleaf and loblolly pine show that the value of stumpage varies considerably for the different products cut. For example, pine sawtimber stumpage currently varies from $3 to $9 per M board feet or (using a converting factor of 150 cubic feet per M board feet) from 2¢ to 6¢ per cubic foot; while pulpwood varies from 40¢ to 80¢ per cord or (using a converting factor of 80 cubic feet of solid wood without bark per cord) from ½¢ to 1¢ per cubic foot. Hardwood sawtimber stumpage varies in value from 2¢ to 4¢ per cubic foot, and chemical wood has nearly the same value as pulpwood. Peeled pine cut for posts, poles, and piling varies in value from 1¢ to 8¢ per cubic foot. It is readily apparent, therefore, that sawtimber being sold for only ½¢ per cubic foot might better be cut into pulpwood and that the forest owner who sells sawtimber stumpage, worth 4¢ per cubic foot, for pulpwood, worth only 1¢ per cubic foot, is receiving only about 25 percent of its marketable value. On the other hand, the owner who sells his sawtimber stumpage to a sawmill operator and then sells his pulpwood and chemical wood (from tops, thinnings, and improvement cuttings) obtains the full stumpage value of his timber.

Estimated Costs and Returns from Continuous Management of Second-Growth Stands

Investigations made by the Southern Forest Experiment Station indicate that the management of shortleaf-loblolly pine forests is financially profitable, the amount of profit derived depending upon the volume and quality of the present growing stock, the productive capacity of the site, the available markets for forest products, and the efficiency of the management. While the net returns per acre per year from heavily depleted and poorly managed forests are very small, well-stocked and efficiently managed properties yield maximum annual returns of $5 or more per acre. Reasonably good management of average stands under existing markets should yield a net income of $1 per acre per year.

A compartment of 1,000 acres in southeast Arkansas with typical second-growth sawtimber is described here to illustrate the financial possibilities of management. The original timber stand was cut heavily about 25 years ago. A recent cruise of this property shows 2,982 board feet of pine (over 13 inches d.b.h.) per acre, 1,000 board feet of rather poor-quality hardwoods (over 13 inches d.b.h.), and considerable young growth. Figure 1 shows the number of trees, basal area, cubic feet, and board feet by diameter- and timber-classes. Figure 2 shows in basal area per acre the present growing stock, a proposed improvement cutting of the present stand, and estimated growing stock and proposed cuts at the end of each of four successive 10-year cycles. Detailed growth studies of this timber show that the pine volume is growing at a rate of 6-7 percent compounded annually.

If 586 board feet per acre of pine are cut in 1937 to improve stand conditions, it is estimated that by 1947, i.e., at the end of a 10-year cutting cycle, the residual pine stand of 2,396 feet per acre will have grown to a volume of 4,528 board feet, or at the rate of 213 feet per acre per year.

This assumes the same rate of diameter growth by size-classes as was determined for the stand before the improvement cutting, and should give a conservative figure, since many of the poorer, less-thrifty trees were removed. In 1947 it is proposed to harvest 25 percent of the sawtimber, or 1,132 feet per acre, thus reducing the stand from 4,528 feet to 3,396 feet. Assuming the same rate of growth, by the end of the second cutting cycle, or in 1957, the stand should have increased to 5,933 feet, which represents a growth rate for the second 10-year period of 254 feet per acre per year. A cut in 1957 of 30 percent of the growing stock, or of 1,780 feet, would reduce the stand to about 4,153 feet per acre, but growth during the third cutting cycle would build it up to 6,967 feet by 1967, or at the rate of 281 feet per acre per year. Another cut of 30 percent of the growing stock in 1967 should yield 2,090 feet per acre and leave 4,877 feet of sawtimber. During the fourth cutting cycle, growth at the rate of 303 board feet per acre per year would build the sawtimber up to 7,908 feet per acre. A cut in 1977 of 30 percent of this volume would yield 2,372 feet per acre and cut the stand back to 5,536 feet per acre. Thus, during a 40-year period, it is estimated that the stand would yield 7,960 feet per acre from five cuts, although the first cut, made when the property was first put under management, is really a cut of material accumulated from growth during the years previous to management. The total growth during the 40 years is estimated as 10,514 board feet per acre, or an average of 263 board feet per acre per year. The gain per acre in the reserved growing stock from the beginning of the first cutting cycle (2,396 feet) to the beginning of the fifth cutting cycle (5,536 feet) would then be 3,140 feet.

Table 3 shows at each cutting cycle the estimated volume per acre of growing stock before and after cuts, the volume of cut, the gain in volume of the residual stand, and the total and annual volume growths.

Table 3. Estimated sawtimber[1/] and cuts and growth per average acre during four 10-year cutting cycles in second-growth loblolly and shortleaf pine

Item	1937	1947	1957	1967	1977	40-year period
	Board feet (International ¼-inch kerf rule)					
Stand before cutting	2,982	4,528	5,933	6,967	7,908	--
Stand after cutting	2,396	3,396	4,153	4,877	5,536	--
Growth cut	586	1,132	1,780	2,090	2,372	7,960
Growth added to growing stock	--	1,000	757	724	659	3,140
Total growth during the period	--	2,132	2,537	2,814	3,031	10,514
Average annual growth during the period	--	213	254	281	303	263

1/ Trees over 13 inches d.b.h.

It should be emphasized that the figures in table 3 are only estimates or predictions. Although based on an existing stand of 1,000 acres of shortleaf and loblolly pine and on the present diameter growth rates of this stand, they are not based on actual measurements of growth and yields as measured at the end of a period of management. Many unforseen contingencies may arise during 40 years of forest management, but since these figures do not provide for increased growth rates under good management, it is believed that they are conservative. A further word of caution should be added, however: these figures apply only to the conditions found on the 1,000 acres referred to, and cannot safely be applied to other holdings without a careful consideration of local conditions, which may produce radically different yields and growth.

The possibilities of growth and yields from hardwood sawtimber associated with pine are not predicted because current studies of volume and value yields of hardwoods have not yet been completed. The great variety of species complicates the problem. Although hardwoods play a minor role in the loblolly-shortleaf pine-hardwoods type, hardwoods under good management can contribute to the total income, and the possibilities in this direction should be developed.

If each cut is made on a cultural basis, that is, if trees of poor form and vigor are removed, and if vigorous, clear-stemmed trees are reserved, with as large a proportion in merchantable size classes as is financially feasible, the quality and value of the growing stock will be increased continually. Figure 2 shows, for example, that in 1937 there is only a fraction of a pine tree per acre in the 22-inch class and that none are in larger classes, while in 1977 one may expect to find a few pine trees as large as 32 inches d.b.h. In 1937 the volume of pine trees in the large-sawtimber class is only 104 board feet per acre, but by 1977 it is estimated that the reserved stand will have about 2,100 board feet in this class. With larger sizes and better quality timber to select from, the average value per M board feet of stumpage cut from the stand in 1977, without any assumption of an increase in the general market prices of stumpage, may well be at least twice the present value, although full realization of such values may have to await the general recognition of log grades. Stumpage and logs are not now commonly graded in the South, but they doubtlessly will be within a few years, inasmuch as such grading is highly desirable and is now practiced in most of the other forest regions.

Assuming that the stumpage values per M board feet of cut and growth in 1937 is $4, in 1947 is $5, in 1957 is $6, in 1967 is $7, and in 1977 is $8,[6/] then the values of the volumes of the cut, the growth, and that part of growth added to the growing stock (given in table 3) are as shown in table 4.

Table 4. Estimated value of sawtimber cuts and growth per average acre during four 10-year cutting cycles in second-growth loblolly and shortleaf pine

Item	1937 at $4 per M ft.	1947 at $5 per M ft.	1957 at $6 per M ft.	1967 at $7 per M ft.	1977 at $8 per M ft.	40-year period
Growth cut	$2.34	$5.66	$10.68	$14.63	$18.98	$52.29
Growth added to growing stock -	5.00	4.54	5.07	5.27	19.88	
Total growth during the period -	10.66	15.22	19.70	24.25	69.83	
Average annual growth during the period -	1.07	1.52	1.97	2.42	1.75	

From these figures it is seen that on 1,000 acres of typical second-growth pine with 2,982 board feet per acre, a light cut of 586 feet per acre, or a total of 586 M board feet for the whole property, will yield an immediate income of $2.34 per acre or a total of $2,340 if stumpage is worth $4 per M board feet. During the first 10-year cutting cycle, growth amounts to about 213 board feet per acre per year or a total of 2,132 M feet on the 1,000 acres during the 10-year period. This 2,132 M feet, valued at $10,660 if stumpage is worth $5 per M board feet, is the maximum volume that can be cut from the property without depleting the growing stock and gives the equivalent to an annual income of $1.07 per acre. Because the property is understocked, it is advisable to cut only 25 percent of the sawtimber, or 1,132 board feet per acre, and to add 1,000 board feet to the growing stock. The value of the total cut on the property is then $5,660, representing an annual income of 57¢ per acre, and the value added to the growing stock is $5,000 or 50¢ per acre per year. It should be pointed out that this addition to the growing stock can be cut at any time, if necessary. If left uncut during the next 10 years not only will it increase in volume at a rate of about 6 percent compounded annually, but it also increases in quality so that it is worth about $1.00 more per M board feet. Table 4 indicates that the value per M board feet of the annual growth per acre increases with each successive cutting cycle from $1.07 to $1.52, then to $1.97, and finally to $2.42. The total values of the proposed cuts for the 1,000 acres also increase as follows: 1st cut of about 20 percent of the growing stock - $2,340; 2nd cut of 25 percent of the growing stock - $5,660; 3rd, 4th, and 5th cuts each 30 percent of the growing stock - $10,680, $14,630, and $18,980, respectively.

6/ Stumpage values have been increased for each cutting cycle of 10 years because under good management the quality and value of the timber cut continually increase. The standard stumpage price for average second-growth loblolly and shortleaf pine on Forest Service sales in 1936 was $7 per M board feet; since considerably higher prices were received on some sales, the values used evidently are conservative.

In addition to the income from stumpage for pine sawtimber, some income should be derived from pine pulpwood stumpage and from hardwood-sawlog and fuelwood stumpage. Studies made by the Southern Forest Experiment Station indicate that the cubic-foot volume of pulpwood that can be cut from tops, thinnings, and improvement cuttings, equals one-half to the full amount of the total cubic-foot volume of sawtimber cut. These studies show that when the improvement cutting of 586 feet of pine sawtimber is made, approximately 1 cord of pulpwood with a stumpage value of 75¢ can be cut from tops of felled sawtimber trees and from other trees removed in stand improvement work that are unmerchantable for sawlogs. At the end of the first 10-year cutting cycle, it is estimated that another 1½ cords with a stumpage value of $1.13 can be cut.

Merchantability of hardwoods associated with pine is more uncertain. Studies of improvement cuttings for chemical wood indicate that a yield of a cord per acre, with a stumpage value of 50¢, can be removed at the beginning of the first cutting cycle,and that a total income of $1.50 for hardwood sawtimber and cordwood stumpage can be obtained at the end of the first 10-year cycle.

The total income for the 1,000-acre forest from the first cutting in 1937, which is more of an improvement cutting than a harvest cutting, is estimated as follows:

586 board feet of pine sawtimber at $4 per M board feet = $2.34 per acre x 1,000 acres =	$2,340
1 cord of pine pulpwood per acre at 75¢ per cord x 1,000 acres =	750
1 cord of hardwood fuelwood per acre at 50¢ per cord x 1,000 acres =	500
Total income, 1937 =	$3,590

The total income at the end of the first cutting cycle, or in 1947, is estimated as follows:

1,132 board feet of pine sawtimber at $5 per M board feet = $5.66 per acre x 1,000 acres =	$5,660
1½ cords of pine pulpwood per acre at 75¢ per cord = $1.13 per acre x 1,000 acres =	1,130
Hardwood sawtimber and fuelwood at $1.50 per acre x 1,000 acres =	1,500
Total income, 1947 =	$8,290
Value of growth added to growing stock =	5.000
Total value of cut and growth added to growing stock =	$13,290

If the total income per acre for the 10-year period is $8.29, the average annual income per acre is 83¢. When one considers the value of the growth which was not cut but was added to growing stock, the average annual income per acre becomes $1.33.

At the end of four cutting cycles, or in 1977, it is estimated that the income will be as follows:

2,372 board feet of pine sawtimber at $8 per M board feet = $18.98 per acre x 1,000 acres =	$18,980
3 cords of pine pulpwood per acre at $1 per cord = $3 per acre x 1,000 acres =	3,000
Hardwood sawtimber and fuelwood at $3 per acre x 1,000 acres =	3,000
Total income, 1977 =	$24,980
Value of growth added to growing stock =	5,270
Total value of cut and growth added to growing stock =	$30,250

The average annual income per acre for the fourth 10-year period therefore is $2.50, and when the value of the growth added to the growing stock is also considered, the average annual income per acre becomes $3.02.

Again it should be pointed out that all these figures are theoretical and have not been obtained after long years of management, but it should also be stated that second-growth stands with better stocking than that estimated for this stand in 1977 (viz., 5,536 board feet per acre) can readily be found on limited areas, having grown to their present volume in spite of periodic fires and without any management or cultural care. In other words, owners starting their forest management with better stocked stands can expect better returns than those predicted herein, while those owners beginning management with poorer stands and less favorable growing conditions must be content with smaller yields and less income.

The annual costs per acre for forest management in this forest region in 1937 are about as follows:-

Taxes	$0.15
Fire protection	.03
Administrative costs	.03
Technical services of forester and assistants	.04
Total	$0.25

With a gross annual income of about 83¢ per acre during the first cutting cycle, deduction of this total cost of 25¢ leaves 58¢ as the net annual income per acre. On 1,000 acres this totals only $580 per year in cash, but stumpage valued at $500 is also added each year to the growing stock. This stumpage, which grows in volume at a rate equal to more than 6 percent compounded annually and which is estimated to increase in value during a 10-year period about $1 per M board feet, can be liquidated at any time that the owner finds it necessary.

As the returns from forest management increase and growing-stock values are built up, some increase in the annual expenses per acre may be expected, but where rather intensive forestry is practiced and a heavy growing stock is maintained, the following is considered a reasonable statement of cost:

Taxes	$0.25
Fire protection	.08
Administrative costs	.05
Technical services of forester and assistants	.07
Total	$0.45

It will be noted, however, that this increase in costs is not proportionate to the increase in returns under management. With a gross annual income per acre in 1977 of $2.50 and a total cost of 45¢ per acre, the net income is $2.05 per acre per year, and in addition growth valued at 53¢ per acre is added each year to the growing stock. Thus, as the yield improves, the margin of net earnings is materially increased.

This paper, which has reviewed very briefly a subject that would require several textbooks to develop, has necessarily left entirely untouched numerous subsidiary matters; but in conclusion it should be emphasized that the present prospects of profitable management of shortleaf and loblolly pine for sustained yield are bright. In fact, a number of lumber companies and other forest owners in the region where these forest types predominate have definitely adopted the practices recommended in this paper and are finding them more profitable than former cutting methods which removed practically all marketable material. As operators familiarize themselves with the principles of good forest management, undoubtedly they will become progressively convinced of the fact that sustained-yield forest management pays.

SUMMARY

Satisfactory commercial forest management must not only produce continuous yields but it must also raise them to, and sustain them on, an adequate level. A prerequisite for such sustained-yield management in the shortleaf-loblolly pine-hardwood type of forest is dependable protection from fire. If the average area burned per year is limited to less than 1 percent of the total forest area protected, adequate reproduction of pine will generally follow all types of partial cutting, except infrequent, very light or very heavy cuts.

Where pines are reproducing satisfactorily, as they seem to be over most of the shortleaf-loblolly pine region, pine seedlings require no detailed attention in cruising timber. Hence the volume and growth of the merchantable and premerchantable portions of the sawtimber growing stock are generally the only ones that require preliminary detailed determination by size-classes. These preliminary cruises, in order to avoid unwarranted expense, should ascertain total timber stocks and average rates of growth only for the forest as a whole, or for large "working circles" or blocks but not for any of the smaller subdivisions of the property such as individual logging units or compartments, which can be cruised more economically later. Accordingly, these preliminary systematic timber cruises should not attempt to map or locate timber, but should merely try to determine the timber-growing capacity. Where conditions are fairly uniform on tracts of 10,000 acres or larger, the blanket determination of merchantable timber stocks and rates of growth can often be accomplished very economically, as sample plots requiring actual measurements of trees do not total more than 1 percent of the forest area.

The practical purpose of the non-intensive, initial timber cruise is to provide the information essential for a working plan to regulate the current removal of timber, so that the total cut will not exceed the growth. Preliminary forecasts of the growth of merchantable timber volumes are best obtained, after due allowance is made for loss from natural causes, by contrasting present stocks, class by class, with those on the ground 5 or 10 years previously, and by assuming that growth for the next several years will closely approximate the past growth as measured. Such forecasts of periodic growth form the basis for the necessary limitation of the total volume of timber to be cut from the forest during the next period; and to attain a material increase in future yields from forests not up to capacity production, a certain percentage of the growth (perhaps 20 percent) should be reserved if possible by this limitation.

The forest should be divided into compartments of convenient size (500 to 2,500 acres each) to facilitate protection, administration, and management. Roads, fire lines, open fields, streams, etc., can be used for compartment boundaries. Also a history of all cultural operations and yields should be kept for each compartment so that valuable detailed data on timber stands and growth—data not obtained in the preliminary cruise—will gradually accumulate. Pending the acquisition of the more reliable and realistic information resulting from actual experience in forest management, the effort and expense required to prepare a lengthy, rigid, and detailed plan of forest regulation cannot be justified. If the preliminary written plan of management ventures beyond a mere statement of policy, the detailed specifications of such a plan may need to be revised frequently. The general policy and purpose of management, however, must be perpetuated for best results over a long period.

While economic means of regulating the cut require early attention, the most immediately available benefits in organizing a forest for sustained yield are those which result from better silviculture. Fortunately, marked improvement in cultural operations are now feasible over wide areas, largely because auto-trucks, tractors, roads, and other transportation facilities have increased the accessibility of timber. Wherever conditions permit, the growing stock should be enhanced in value (both volume and quality) by cutting frequently and lightly in all accessible stands, constantly removing inferior trees and reserving the better ones. The less promising trees should be eliminated gradually from all merchantable size-classes whenever for any reason they become incapable of further satisfactory increases in volume, quality, or value (i.e., at financial maturity). Cuttings should be made first in those compartments where salvage appears most urgent because of the prevalence of over-maturity, insect depredations, disease, windfall, or fire damage. Early harvesting is also indicated for certain compartments in urgent need of thinning or other improvement cuttings.

Silvicultural marking of all timber for cutting is an art which is vital in the practice of forestry. Based in part on the technology of forest products and tree growth, it nevertheless rests very largely on the judgment of the marker, who should be an experienced man, working under the supervision of a competent forester. Marking crews not only should designate each individual tree to be cut but also should make a complete tally by diameter-classes of all merchantable trees segregated as to whether they are to be cut or left. This procedure not only provides a convenient means of keeping currently informed as to the amount of the cut, but it also produces an accurate but inexpensive inventory of timber resources by compartments. The continued repetition of such complete inventories at each regular cutting will eventually supply the most accurate bases possible for limiting the cut to the growth capacity, because in its simplest terms the net growth of timber on any compartment is the difference between the volumes of merchantable timber at the beginning and end of a cutting cycle.

The crucial question in the commercial application of any constructive program—"Will it pay?"—must be answered separately for each forest, but some outstanding financial aspects bearing on the system of light and frequent selective cuts should be mentioned. After the initial improvement cuttings have removed low-value trees (including numerous small ones), the average size of logs in subsequent cuts should be larger, and for larger trees and logs the cost of logging and milling is appreciably less, while the selling price per M board feet of the lumber produced is greater.

Rapidly developing markets for southern pulpwood offer increased opportunities to promote good forestry practices. These new markets assist partly by permitting more complete utilization of sawtimber, but more especially by making extensive thinning and improvement cutting profitable in smaller and younger timber. Obviously a skillful integration of utilization offers the best possibilities for profit, as the stumpage values of trees which are suitable for lumber, posts, poles, or piles is often four to six times as much per cubic foot as the value of the same timber used for pulp or chemical wood. The high value of certain trees which can meet the exacting requirements of special uses should not be sacrificed, as it commonly is, by marketing this material indiscriminately mingled with logs yielding only low-value products.

Although conditions vary enormously in the shortleaf-loblolly pine-hardwood type of forest, a net annual income of $1 per acre can be expected from reasonably good management of typical second-growth stands (averaging about 3,000 board feet per acre) under existing markets; and it is believed that after several cutting cycles under sustained-yield management, this net income can be increased materially.